Supporting Information

Temporal and Spatial Resolved SPR Imaging of Electric-Double-Layer dynamics in Electrolyte-Gated Transistors with Ionic Liquid

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Complementary Theoretical Basis

Fresnel equations and interference theory were used to analyze the light intensity and phase caused by the refraction and reflection of light waves in the multilayer structure:

$$\mathrm{r}_m = \frac{r_{0,1}^m + r_{1,3}^m e^{2idk_{z1}}}{1 + r_{0,1}^m r_{1,3}^m e^{2idk_{z1}}}, (i = \sqrt{-1}, m = p, s) \quad (1)$$

$$k_{x0} = \frac{\omega}{c}\sqrt{\varepsilon_0}\sin\theta \quad (2)$$

$$k_{zj} = \sqrt{\left(\frac{\omega}{c}\right)^2 \varepsilon_j - k_{x0}^2}, (j = 0,1,2,3) \quad (3)$$

$$r_{j,j+1}^p = \frac{\frac{\varepsilon_{j+1}}{k_{zj+1}} - \frac{\varepsilon_j}{k_{zj}}}{\frac{\varepsilon_{j+1}}{k_{zj+1}} + \frac{\varepsilon_j}{k_{zj}}} (j = 0,1,2) \quad (4)$$

$$r_{j,j+1}^s = \frac{k_{zj+1} - k_{zj}}{k_{zj+1} + k_{zj}} (j = 0,1,2) \quad (5)$$

Formula (1) is Fresnel's equation, where r is the reflection coefficient, m represents p-polarized light and S-polarized light respectively. d is the thickness of Au film thickness, k_x, k_z are wave vectors in different directions. Formula (2) ~ (5) is the calculation formula of reflection coefficient of each layer. Layer 0, 1, 2, 3 are glass layer, metal layer, semiconductor layer and dielectric layer respectively, θ is the incident Angle, ε is the dielectric coefficient of each layer.

According to the principle of SPR, when the polarized light incident sensor prism excites SPR, the intensity and phase of p component of the reflected light change dramatically, while the intensity and phase change of s component are not obvious, and the phase difference between p component and s component is very sensitive to the refractive index of the measuring medium.

Therefore, by using the 1/2 wave plate, the p component and the s component are rotated counterclockwise by 45° and 225° respectively, and then the two interference beams are translated in the exit direction by the beam shifter, then the respective light intensity is:

$$I_1 = \frac{E_i^2\left[r_s^2\cos^2\alpha + r_p^2\sin^2\alpha - 2r_s r_p\sin\alpha\cos\alpha\cos\left(\varphi_p - \varphi_s\right)\right]}{2} \tag{6}$$

$$I_2 = \frac{E_i^2\left[r_s^2\cos^2\alpha + r_p^2\sin^2\alpha + 2r_s r_p\sin\alpha\cos\alpha\cos\left(\varphi_p - \varphi_s\right)\right]}{2} \tag{7}$$

Here, the refractive index related factor (RIRF) is defined:

$$RIRF = \frac{I_1 - I_2}{I_1 + I_2} = \frac{-2r_s r_p\sin\alpha\cos\alpha\cos(\varphi_p - \varphi_s)}{r_s^2\cos^2\alpha + r_p^2\sin^2\alpha} \tag{8}$$

Where α is the polarized angle, φ_p and φ_s are the phases of p light and s light.

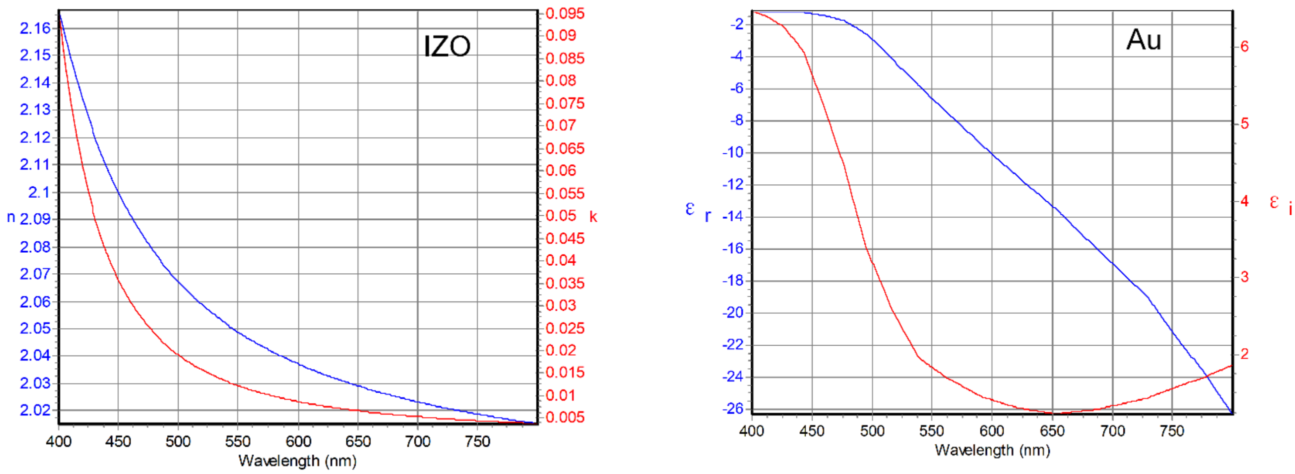

Figure S1. Permittivity measured by an ellipsometric instrument (a) Permittivity curve of IZO film (b) Permittivity curve of Au film

Table S1. Measurement results of film parameters

material	thickness	n	k	ε_r	ε_i
Au	350 Å			-12.215	1.272
IZO	310 Å	2.032	0.007	4.129	0.028

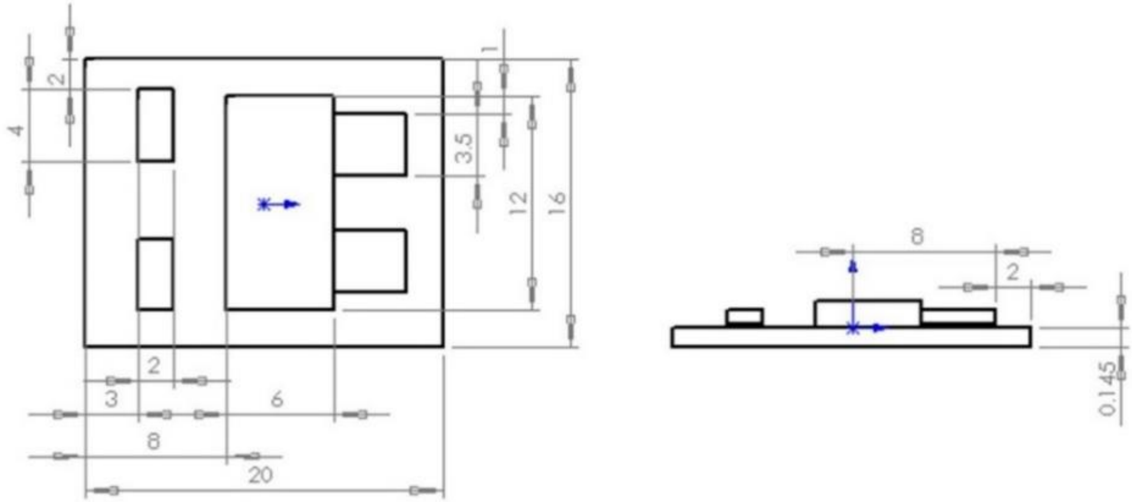

Figure S2. EGTs-SPR Sensor Module Design Coupled with SPR imaging detection structure (length unit: mm)

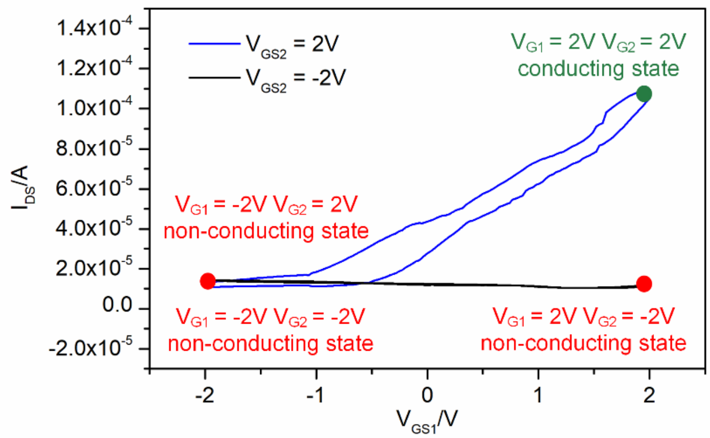

Figure S3. The AND logic operation function realization under the control of dual gate voltage modulation

Table S2. Dual gate voltage modulation AND logical operation truth table.

V_{G1}	V_{G2}	I_{DS}
‘0’	‘0’	‘0’
‘0’	‘1’	‘0’
‘1’	‘0’	‘0’
‘1’	‘1’	‘1’

As shown in Figure S3, the negative gate voltage represents ' 0 ', and the positive gate voltage represents ' 1'. IDS less than 0.04mA indicates ' 0 ', meaning non-conducting state. IDS larger than 0.04mA indicates ' 1 ', meaning conducting state.